[COMMITTEE PRINT]

REPORT ON THE COSTS AND EFFECTS OF CHRONIC EXPOSURE TO LOW-LEVEL POLLUTANTS IN THE ENVIRONMENT

PREPARED BY THE

SUBCOMMITTEE ON THE ENVIRONMENT AND THE ATMOSPHERE

OF THE

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LETTER OF TRANSMITTAL

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, D.C., July 21, 1976.

Hon. OLIN E. TEAGUE,
Chairman, Committee on Science and Technology, U.S. House of Representatives, Washington, D.C.

DEAR MR. CHAIRMAN: I am transmitting herewith a Report on the Costs and Effects of Chronic Exposure to Low-Level Pollutants in the Environment. The report is based on hearings held before our Subcommittee November 7, 10, 11, 12, 13, 14 and 17, 1975; on statements submitted by professional societies, other organizations, and interested individuals; and on other material.

I am happy to acknowledge the assistance of Dr. Renee Naves, an American Chemical Society Fellow, and the Congressional Research Service, Library of Congress, in preparing this document.

This report is particularly timely, and contains much information which I believe will be very useful to Members as they consider legislation now before the Congress. I commend the report to you and the other Members.

Sincerely,

GEORGE E. BROWN, JR.,
Chairman, Subcommittee on the Environment and the Atmosphere.

I.—INTRODUCTION

The Subcommittee on the Environment and the Atmosphere of the House Science and Technology Committee, George E. Brown, Jr., of California, Chairman, held hearings in the Fall of 1975 on the costs and effects of chronic exposure to low-level pollutants. The hearings encompassed seven days of testimony from November 7 through November 17, 1975. In addition to the testimony presented orally the subcommittee received a large number of written responses from a wide variety of experts who were invited to contribute to the record. Subjects under scrutiny included chronic pollution effects on human health, on agriculture, on ecological systems in general, and on the earth's climate.

By "low-level pollution" the Subcommittee understood roughly those levels of pollutants which are at the low end or below the levels of ordinary ambient standards or levels of direct perception. By "effects of chronic exposure to low-levels of pollution" the Subcommittee understood those effects which are generally slow in developing and which represent a broad response of a species, or ecological or physical system, to an environmental insult which has been occurring over a long period of time.

The Subcommittee has jurisdiction over all aspects of environmental research programs throughout the Federal government, and was attempting to ascertain what implications should be drawn from the state of understanding of chronic pollution effects, in order to better oversee these Federal programs.

II.—BACKGROUND OF THE HEARINGS

In an industrial society there are very few who are not aware of acute pollution problems. Air pollution episodes, fish kills, and blighted forests and fields surrounding cities or smelters are all too readily apparent. A great many of our pollution standard setting efforts, and environmental research investigations, are aimed at preventing these obvious incidents.

However, there are widespread areas of serious but less obvious cause for concern in the effects of long term, chronic exposure to low-levels of pollution. These effects are often not at all measurable by observation of individuals. Instead, they are usually manifest only in statistical studies covering long time periods. Such effects might involve changes in the incidence of cancer or birth defects, lowering of crop yields or quality, changes in the types or numbers of species in inland water or ocean eco-systems, or changes in long term climate patterns.

These long term, chronic effects tend to be neglected in standard-setting debates. As the Subcommittee's hearings made obvious, they are exceedingly difficult to quantify, especially with our current laboratory techniques and primitive health and ecosystem monitoring methods. Yet the threat of chronic pollution exposure may well be profound. Just as the chronic effects are slow in becoming manifest, they may be very difficult to reverse quickly. Moreover, though effects or risks may be small in terms of the health of an individual person or plant, they are often spread very widely throughout the population. Thus, small individual effects and risks, after being multiplied by very large numbers of individuals exposed, can represent a very great cost or danger.

In much the same way that low-level chronic pollution and its effects are often neglected in standard setting considerations, they are also often neglected in research planning. Environmental research funding has tended to follow dramatic crises, and funding limitations have had the effect of squeezing out all but the most simplistically obvious concerns. The neglect of chronic effects in research amplifies, of course, the parallel neglect in standard setting. With little research background the hard information about chronic effects is lacking, and standard setting has to proceed, if at all, on a soft foundation of poorly understood probabilities and extrapolations.

We are not totally without information, however. Enough fragmentary evidence has emerged to convince many health scientists, agronomists, ecologists, and meteorologists that the potential of the hazard is enormous. Risk of cancer is now known to correlate very strongly with where a person lives and works. Ozone, a major threat to plant health, is now so widespread from long term atmospheric transport of chronic air pollutants that its level is often as high in rural agricultural areas as in urban settings. Tree ring patterns suggest a general

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slowing down of forest growth in recent years, and "rain shadows" and other climate changes in and around urban areas are statistically measurable. These observations are all clear warnings of influences on our health and biosphere which are building inexorably, but of which we have only begun to be aware.

The purpose of the hearings was to raise public and Congressional awareness of the bits of information pointing to chronic, low-level pollution as a serious problem, possibly more threatening than acute local episodes. They were meant to warn against complacent attitudes toward looseness or relaxation of environmental standards in the absence of short-term acute effects. They were intended also to illustrate just how scant our scientific knowledge is in this domain, and to solicit suggestions as to what can be done to strengthen our understanding and enable us better to assess the trade-offs between tolerating polluting actions and protecting human and biosphere health. Finally, they were meant to examine whether this was an area where a relatively small research investment might bring greatly multiplied benefits in resolving economic and health cost ambiguities.

III.—CONCLUSIONS

1. Effects of chronic, long-term pollution exposure are indeed serious, though poorly understood.

Dr. David Rall, Director, National Institute of Environmental Health Sciences, pointed out in the hearings that "we are constantly learning that many environmental exposures we previously thought were limited to the occupational realm, are in fact affecting the general population. In 1970 the dollar cost associated with environmental disability was estimated at approximately $38 billion. When the question is broadened to what is the cost of environmental pollution in general, it is clear that the cost is enormous." Similarly, agricultural experts submitted evidence that damage to crops and forests was extensive even at pollutant levels well below those allowed by Federal secondary air quality pollution standards.

2. In attempting to assess accurately the effects of chronic pollution we are hampered by a lack of baseline information against which to measure man-made perturbations.

Many experts, in health, ecology and meteorology, decried our lack of monitoring systems or other means to detect changes in human and ecological health. We are unable to assess potentially dangerous trends because of near total ignorance of the extent of natural fluctuations in many health and ecological variables.

3. In attempting to assess accurately the effects of chronic pollution we are hampered by an inadequate basic research base.

Synergistic effects of several pollutants or other stresses, the transformation and long-range transport of pollutants, and long term studies of large populations, are typical of the subjects which have been inadequately addressed in contemporary crisis-oriented environmental research.

4. The cost of research to resolve many of these ambiguities is much less than the potential costs of proceeding in ignorance.

Dr. Edward Burger, Jr., of the staff of the Science Advisor to the President, stated in this context that "the absence of knowledge appears, in the long run, to be much more expensive and clearly encourages bad public policy. The value of foods and drugs over which the FDA exercises regulatory control will be approximately $143 billion this year. Costs of meeting legislated automobile emission standards are by any estimate a very large figure. Errors in regulatory judgment are necessarily expensive errors."

5. Progress in dealing with chronic pollution is hindered by a lack of coordination among Federal environmental programs, and between those programs and State and local efforts.

Chronic, low-level pollution effects usually require multi-disciplinary scientific approaches for understanding, and multi-agency approaches for assessment and control. Many experts expressed frustra-

tion at the lack of coherence in Federal programs, and the lack of effective mechanisms for inter-agency coordination.

6. There may be needed changes in the legal basis of standard setting to better match the problems of chronic pollution.

Instead of direct "cause and effect" evidence, consideration should be given to explicitly basing standards on statistical changes, epidemiology, and probabilities of harm even over the long term. The American Medical Association stated that "ideally, the basis of standards should move from proven effects to probabilities of risk."

IV.—RECOMMENDATIONS

1. The Congress and the Executive should undertake a careful examination of means to reorganize the Federal environmental research program.

Central to such an examination should be the possibility of formulating an over-all environmental research plan, aimed at better allocating scarce resources to prioritized goals. More effective over-all leadership, helping to insure coordination among Federal programs and between them and State and local efforts, may be needed. Reorganization should be aimed at establishing a better information flow concerning pollution threats, with more rapid exchange of data and methodology in better standardized formats. A possible outline for such a reorganization is given in Appendix I.

2. Executive agencies involved in health, ecosystem, and climate research and measurement should examine the feasibility of creating comprehensive monitoring systems to establish baseline information and provide advance warning of unfavorable trends.

These efforts will require more detailed interagency coordination than has been evident in the past, and should be undertaken as explicit interagency programs. With careful organization, it may be possible to make considerable progress by using existing information gathering systems more effectively—instead of wasting valuable data and observations as is done today. The United States should also take a leadership role in supporting global climate and ecological monitoring.

3. Executive agencies involved in health programs and statistics should examine the feasibility of a comprehensive national epidemiology program aimed at detecting health effects of chronic pollution.

In this area, too, organization and coordination of existing information may be more important than seeking to obtain new data. Much effort will be needed to effectively link State and local statistics to an over-all national picture. The needs for protection of individual privacy will have to be reconciled with the needs for early warning of health trends.

4. The Executive agencies should immediately examine the feasibility and make recommendations for a chemical health effect screening program.

This could be accomplished with relative economy by proceeding with carefully chosen priorities. Those chemicals released to the environment in the largest quantities could be screened first, initially using one of the rapid and inexpensive methods for estimating carcinogenic potential. Those showing positive signs of danger in the initial tests could then be subjected to more extensive long-term animal testing. Research in developing rapid and economical screening tests for health effects should be given high priority.

5. Health research funding should more clearly reflect the proportion of disease that is linked to environmental factors.

Only about 10% of the national cancer program has gone into environmental chemical carcinogenesis, despite a consensus on this as a dominant causal factor. Similar misallocation of funds appears to exist in study of respiratory and cardiovascular disease. Many experts agree that emphasis should be placed on prevention of debilitating environmental health effects, instead of only on cure.

6. Environmental research funding on chronic pollution effects should be more keyed to the potential costs of these effects.

In the area of climate effects, as just one example, all agree that very small perturbations could have terribly costly results. Yet research funding in this area in no way reflects the economic potential of the information to be derived.

7. Better methodologies are needed for assessing pollution control benefits in cost-benefit equations.

This is especially true in agriculture, where we have moved from a period of surplus to a period of shortage. Pollution-induced reductions of agricultural yields result in very significant dollar costs, and we should not be in ignorance of them. An interagency effort between the Department of Agriculture and the Environmental Protection Agency should be the best way to proceed.

V.—WITNESS LIST

Hearings on Costs and Effects of Chronic Exposure to Low Level Pollutants in the Environment

Friday, November 7

COST ANALYSIS—HEALTH

Mr. John A. Busterud, Member, The Council on Environmental Quality, accompanied by Dr. Warren Muir, Senior Staff Member for Environmental Health.

Dr. Lester B. Lave, Professor and Chairman, Department of Economics, Graduate School of Industrial Administration, Carnegie-Mellon University, Pittsburgh, Pa., accompanied by Dr. Eugene Seskin.

Dr. James Liverman, Assistant Administrator for Environment and Safety, Energy Research and Development Administration, accompanied by Dr. Chester R. Richmond, Dr. John B. Storer, Dr. Alvin M. Weinberg, Dr. James V. Neel, and Dr. Warren Sinclair.

Monday, November 10

HEALTH

Dr. Roy Albert, Acting Deputy Assistant Administrator for Health and Biological Effects, Environmental Protection Agency, accompanied by Dr. John L. Buckley, Consultant in Research and Development, Former Deputy Director for Programs Integration at EPA.

Dr. Edward J. Burger, Jr., Member, Staff of the Science Advisor to the President and Science and Technology Policy Office, National Science Foundation.

Tuesday, November 11

HEALTH—EPIDEMIOLOGY

Dr. David F. Rall, Director, National Institute of Environmental Health Science and Chairman HEW Committee to Coordinate Toxicology and Related Programs, accompanied by: Dr. John Finklea, Dr. Marvin Schneiderman, and Dr. Robert N. Hoover.

Dr. Marvin S. Legator, Professor, Brown University and the Miriam Hospital, Providence, R.I.

Wednesday, November 12

AGRICULTURE AND ECOLOGY

Dr. Paul Vander Myde, Deputy Assistant Administrator of the Agricultural Research Service, USDA, accompanied by Dr. Howard Heggestad, Dr. Walter W. Heck, and Dr. Donald D. Kricek.

Dr. O. C. Taylor, University of California, Riverside, Calif.

Dr. William J. Manning, Suburban Experiment Station, University of Massachusetts.

Dr. Stanley R. Auerbach, Director, Environmental Science Division, Holifield Laboratory, Oak Ridge, Tenn., accompanied by Dr. John Hanson, University of Illinois, Dr. Patrick Coyne, Lawrence Livermore Laboratory, and Dr. Lee Eberhardt, Pacific Northwest Laboratory.

Thursday, November 13

CLIMATE

Dr. Edward S. Epstein, Assistant Administrator, Environmental Monitoring and Prediction, National Oceanic and Atmospheric Administration.

Dr. James McQuigg, Director, Center for Climatic and Environmental Assessment, National Oceanic and Atmospheric Administration, Columbia, Mo.

Dr. Joseph Knox, Atmospheric and Geophysics Division, Livermore Laboratory, Livermore, Calif.

Friday, November 14

WEATHER—WILDLIFE—WATER

Dr. Helmut Landsberg, Acting Director, Institute for Fluid Dynamics and Applied Mathematics, University of Maryland.

Dr. Lucille Stickel, Director, Patuxent Wildlife Research Center, U.S. Fish and Wildlife Service.

Dr. Robert Harris, Environmental Defense Fund, accompanied by Jacqueline Warren.

Monday, November 17

ASSESSMENT—NEED FOR STANDARDS

Dr. Norman Milleron, Berkeley, Calif.

Dr. James McNesby, Chief, Office of Air and Water Measurement, accompanied by Dr. Philip Lafleur, Chief, Analytical Chemistry, National Bureau of Standards.

Mr. Dick Mack, Head, Electronics Department, University of California, Berkeley, Calif.

Mr. Grover C. Wrenn, Chief, Health Division of Standards Development, Occupational Safety and Health Administration, accompanied by Mr. Benjamin Mintz, Associate Solicitor of Labor, Occupational Safety and Health Administration.

VI.—HEARING OUTLINE AS PROVIDED TO WITNESSES

Current Knowledge About Costs of Chronic, Low-Level Environmental Pollution

(Relation to Research Needs and Standard Setting Approaches)

Hearing Objectives

1. To increase awareness of the effects and costs of chronic, low-level exposure to man-made pollutants, on human health, agriculture, climate, and other aspects of the biosphere.

2. To indicate any needed changes in research emphasis, organization, or funding to cope with needs for intelligent standard setting in this area.

N.B. Please be specific; illustrate general statements with examples, write for the intelligent, interested layman; where appropriate submit copies of relevant articles, etc.

Human Health

I. What are the major kinds of threats in the chronic, low-level pollutant exposure area, e.g., in general health, birth defects, carcinogenic and mutagenic effects?

II. What is known about dose-response characteristics for exposures of this type?

A. What is the comparison with the state of knowledge for exposures to ionizing radiation?

B. What extrapolations can be made from dose-response data on acute, high-level exposure?

C. What range of cost estimates for health effects can be inferred from the range of possible dose-response curves for effects in actual health care, premature aging, loss of work-days, inefficiency, etc.

III. What are the ambiguities in prediction of chronic, low-level pollution effects on health (as illustrated by case histories)?

A. What are the roles of repair mechanisms, metabolic processes, synergistic and antagonistic interactions of pollutants, etc.? That is, how do antagonistic effects lead to ambiguities.

B. Is chemical theory able to predict health effects of pollution? What contribution to predicting effects can theory make?

C. What are the limiting factors in removing the ambiguities in prediction?

IV. What are the ambiguities in measurement of effects of chronic, low-level pollution exposure?

A. What are the problems in gathering statistically significant data?

B. What are the problems in relating effects to uncontrolled exposure?

C. What limits are placed on data-gathering by needs for protection of privacy?

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D. What are the limiting factors in removing measurement ambiguities?

V. What research avenues or organizational changes are promising to resolve prediction and measurement ambiguities?

A. What is the possibility than one can measure molecular properties and derive from them predictions of health effects?

B. What possibilities exist for establishing firm relationships between carcinogenic, mutagenic and birth defect effects of chemicals?

C. What prospects exist for much more effective epidemiological studies?

D. What changes in research emphasis, funding, or organization are needed to pursue the promising pathways described in the answers to above, and to permit more intelligent, and more legally and politically defensible standard setting?

1. What are implications of recent case histories in standard-setting for this question?

2. Do research and development programs have to be re-designed to meet new concepts of establishing reasonable risk, reasonable lack of risk, systems interactions, total ecological planning, trend analysis. etc.?

3. Are current laboratories and manpower pools adaptable to new priorities?

4. Are the needs for standardized testing methods and statistically useful data pointing to much greater need for technology exchange between research organizations?

5. Are new types of review and certification procedures needed to satisfy legal, political and economic realities in standard setting?

6. Do local roles and needs in standard setting indicate a need for greater emphasis on local research and development capability?

7. Is the magnitude of current research and development efforts appropriate to the magnitude of the problem of low-level chronic pollution effects?

8. What legislative actions are indicated by these needs?

VI. What changes in standard setting approaches are indicated by the state of knowledge of chronic, low-level pollution effects on health?

A. Should the basis of standards move from proof of effects to probabilities of risk?

B. Should standards be considered provisional with methodology for continual adjustment based on information development?

C. Should there be more recognition of the necessity for political, philosophical or social standards in areas of high uncertainty?

D. How can a wide cross-section of non-scientific groups be brought into the process of standard setting, in the full range of cases of fairly firm to very shaky scientific data bases?

E. What legislative actions are suggested by any needs for change in approaches to standard setting?

Agriculture and Biosphere

I. What are the major kinds of threat in the chronic, low-level pollutant exposure area—from the viewpoint of crop yields, quality of product, and susceptibility to disease, or biosphere productivity and diversity?

II. What kind of dose-response characteristics are known for exposure of this type?

A. What range and type of extrapolations in dose-response curves can be made from data on acute, high-level exposures?

1. What range of cost estimates for agricultural and biosphere effects can be inferred from the range of possible dose-response curves—in decreased yields or quality?

B. What are the limiting factors in determining these dose-response curves?

III. What are the ambiguities in prediction of chronic, low-level pollution effects on agriculture and biosphere especially as viewed by case histories in this area?

A. What are the roles of repair mechanisms, metabolic processes, synergistic and antagonistic interactions of pollutants, etc., in these ambiguities as well as species specificity in all of these?

B. What is the role of prediction from theories of chemical structure in indicating health effects of pollutants?

C. What are the limiting factors in removing the ambiguities in prediction?

IV. What are the ambiguities in measurement of agriculture and biosphere effects of chronic, low-level pollution exposure?

A. What are the problems in gathering statistically significant data?

B. What are the problems in measuring effects from uncontrolled exposure?

C. What are the limiting factors in removing measurement ambiguities?

V. What research or organizational changes are promising to resolve prediction and measurement ambiguities?

A. What possibilities exist in new molecular assays of potential pollutant activity in agricultural production?

B. What are the relative prospects in cost-effectiveness for land-based as opposed to satellite monitoring systems?

C. Are there any areas where promising breakthroughs in methodology are likely?

D. What changes in research emphasis, funding, or organization are needed to pursue promising pathways, and to permit use of agricultural pollution damage costs in legally and politically defensible standard setting?

VI. What changes in standard setting approaches are indicated by the state of knowledge of chronic pollution effects on agriculture and the biosphere?

A. Should the basis of standards move from proof of effects to assessment of probability of risk?

B. Should standards be considered provisional with methodology for continual adjustment based on information development?

C. Should there be more recognition of the necessity for non-scientific standards in areas of high uncertainty?

D. How can a wide cross-section of non-scientific groups be brought into the process of standard setting, in the full range of cases of fairly firm to very shaky scientific data bases?

E. What legislative actions are suggested by these needs for change in approaches to standard setting?

Climate

I. What are the major kinds of threats of climate perturbations due to chronic release of pollutants?

II. What kind of dose-response characteristics are known for man-made perturbations of the climate?

A. What range and type of extrapolations in dose-response curves can be made from data on natural perturbations of climate or geologic records?

1. What range of cost estimates for deleterious man-made climate effects can be inferred from the plausible range of possible dose-response curves?

III. What are the ambiguities in prediction of chronic pollution effects on climate, either locally or globally?

A. What are the roles of synergistic or antagonistic interactions of these effects, either with each other or natural phenomena, in these ambiguities?

B. What are other limiting factors in removing prediction ambiguities?

C. Are there instructive case histories in illustrating predictive capabilities?

IV. What are the ambiguities in measurement of climate effects of chronic man-made pollution?

A. What are the problems and limiting factors in gathering statistically significant data?

B. What is the most cost-effective monitoring system for measurement in various areas: ground-based, satellite, biological indicators, etc?

C. How much is the lack of baseline data a limiting factor in sensing man-made trends? Is study of natural perturbations and geologic records the best manner to determine base-line data?

V. What research avenues are promising to resolve prediction and measurement ambiguities?

A. What changes in research emphasis, funding, or organization are needed to permit intelligent, and legally and politically defensible standard setting based on climate effects of pollution?

VI. What changes in standard setting approaches are indicated by the state of knowledge of chronic pollution effects on local or global climate?

A. Should the basis of standards move from proof of effects to assessment of probability of risk?

B. Should standards be considered provisional with methodology for continual adjustment based on information development?

C. Should there be more recognition of the necessity for non-scientific standards in areas of high uncertainty?

D. How can a wide cross-section of non-scientific groups be brought into the process of standard setting, in the full range of cases of fairly firm to very shaky scientific data bases?

E. What legislative actions are suggested by these needs for change in approaches to standard setting?

VII.—SUMMARY OF HEARINGS

A. Health Effects

There was a remarkable consistency in the testimony of the witnesses on the issue of the chronic health effects of pollutants. This consistency should not be misinterpreted, however, to suggest any complacency regarding the problem. In fact, there was a tendency throughout the hearings to emphasize the very difficult nature of developing the data needed to reduce the impact of toxic substances on total population morbidity and mortality. The major themes reiterated during these hearings included the enormity of the problem, the need for better techniques for delineating the problems, and the place of risk/benefit analysis for developing priorities and supporting the imposition of control strategies.

PREDICTION OF THE HEALTH EFFECTS OF POLLUTANTS

All of the witnesses mentioned to some degree the neglible data base which is available on health effects as viewed from the perspective of the large number of substances known to be present in the environment. Grover C. Wrenn, Occupational Safety and Health Administration, and Dr. David Rall, Director, National Institute of Environmental Health Science estimated that there are some 15,000–20,000 or more suspect toxic chemicals on which there are some data; an immediate attempt is being made to develop more specific information on about 1,500 of these substances. As Dr. Wrenn indicated, in a few instances it is possible to identify specific etiological or causal agents in some occupational situations, but this is the exception rather than the rule for most chemicals. Dr. Rall emphasized the magnitude of the problem by pointing out that about 500 or more new substances are introduced each year.

Dr. Roy Albert, Acting Deputy Assistant Administrator for Health and Biological Effects, Environmental Protection Agency, acknowledged that we really don't know the effect on large populations of low levels of pollutants. As Dr. Edward J. Burger, National Science Foundation, put it—for regulatory purposes there is a very thin fabric of knowledge about the effects of low levels of pollutants.

Some investigators and other observers of this issue have suggested that there may be some hope in reducing the magnitude of the problem if it becomes possible to find correlative effects of compounds with similar chemical structure. There did not seem to be any real agreement among the witnesses, however, that this approach offered any promise in the very near future. Dr. John B. Storer, who accompanied Dr. Liverman of the Energy Research and Development Administration to the hearings, suggested that the use of chemical theory, as derived from basic studies of chemical effects and possibly extended

to general effects, will be of only moderate usefulness in the final analysis of health effects. Mr. Busterud, of the Council of Environmental Quality, also believes that predicting potential health effects on the basis of chemical structure alone gives only a part of the needed information—ultimately, toxicological testing will always be required.

According to Dr. Rall, the scientific community is still in the position of being unable to anticipate all needs for specific kinds of health effects data. In one example he cited, when the danger concerning the effect of asbestos as an air pollutant was identified, sufficient test data were available to correlate such effects as respiratory disease (and lung cancer) with asbestos as a pollutant. And yet, despite this public attention to asbestos as a pollutant, the community of toxicologists had not completed biological systems tests of asbestos so that when the concern about oral ingestion of asbestos developed, there were no data to examine the risk from this route of administration. Thus, as with other incidents in the past, studies of the health effects of pollutants too often continue to be incompletely evaluated via all potential routes of exposure.

TESTING TO DETERMINE HEALTH EFFECTS

According to the testimony provided on this subject, testing will certainly continue to be an essential part of evaluation and will be an expensive and time consuming process. There was some difference in emphasis as to the relative priorities for testing. Dr. Busterud apparently believes that the most important effects of toxic substances are the mutagenic and carcinogenic effects. Mutagenic effects are of particular importance because these effects can be transmitted for generations and have the potential for modifying entire population characteristics. As pointed out by Dr. Marvin S. Legator, Professor at Brown University, and an expert on mutagenic effects, mutagenic testing and screening are relatively new concepts, having evolved rapidly within just the past 6–8 years. It is still necessary to use a battery of mutagenic tests in the absence of any single definitive method of testing.

Dr. James Neel, who accompanied Dr. Liverman, briefly compared the state of knowledge in the study of radiation effects with the efforts now being exerted on the study of toxic chemicals. As he commented, in the studies in Japan it was certainly to be expected that if effects were to be readily identified at all, certainly, mutagenic effects should have been observable in the progeny of those individuals subjected to atomic weapon effects in Hiroshima and Nagasaki. And yet, they are still unable to demonstrate in their observations any clearly significant incidence of genetic damage; but, neither can certain small but meaningful changes be wholly excluded. As he pointed out in his discussion, radiation effects are influenced by many factors. These same problems will be encountered with greater intensity in studies of the effects of multiple exposure to many chemicals.

As to the relative importance of empirical testing versus basic research on chemical effects, Dr. Warren Sinclair, of the Argonne National Laboratory, indicated that the current state of knowledge of the molecular basis of mutagenic (and carcinogenic) change is quite inadequate. Thus, while basic research of expanded scope is necessary to develop these data, it will obviously still be necessary, in order to

get on with the task of controlling toxic substances, to continue to use a series of empirical tests in animals.

On other occasions, representatives of the National Cancer Institute have indicated that full costs of test for carcinogenicity may run as much as $100,000 and take as long as 2–3 years to complete. Dr. Rall added that whole animal studies of the complete range of toxicological studies might cost as much as $200,000 per test series (per compound). He supported the other witnesses in their evaluation of the need for improved, less time consuming, and less expensive tests. These analyses mean of course that not only does the effectiveness of existing tests need evaluation, but that a program of new test development is obviously necessary.

In his discussion of health effects testing, Dr. Alvin Weinberg, Director of the Institute for Energy Research, directed attention to an issue that is of continuing concern in many regulatory agencies—namely, the question as to what a zero level of pollutant really means. In testing for health effects, and particularly in cases involving the Delaney anticancer clause of the Food, Drug, and Cosmetic Act, Dr. Weinberg suggested that a zero level really means a level which cannot be measured or that this is a level which shows no effect. This problem, when added to the difficulty of investigating low dose effects, makes the task of deriving conclusions from health effects tests about the dangers of low levels of pollutants very dependent upon the instrumentation available. It also means that as technology progresses, it is very likely that the knowledge data base may change with regard to evaluation of test results.

Finally, with the limited resources available, it was evident from the various discussions, that programs of testing for health effects will require that information on production, use, distribution, chemical composition and other physical factors as well as the prospective population exposures, will all be required in order to set testing priorities. Dr. Rall and several others dwelt briefly on the difficulty of studying the synergistic or interacting effects of chemicals. Most classical programs of testing for health effects involve single substance testing under rigid control conditions. While these approaches provide essential data, there is concern that effects of simultaneous exposure may be significant but overlooked unless the capability to conduct such tests is improved. The obvious difficulties in conducting such tests are compounded as the number of substances studied simultaneously is increased.

Dr. Chester Richmond, Associate Director for Biomedical and Environmental Sciences, Oak Ridge National Laboratory, indicated that there is an essential requirement to learn more about the 70% or more of environmentally induced cancer which is so often reported. He asked the question as to whether these are real effects, and whether they are primarily industrially (man produced) or environmentally (natural) related. The answer to this question could be critical in the allocation of resources. In this regard, like several others in their testimony, he pointed out that while the need to gain a better understanding of the effects of very low doses of toxic chemicals is a test problem of great significance in standards setting, he believes that we may never fully understand such effects, particularly within a time

frame of significance to the solution of current problems. As he pointed out further, even in the study of radiation effects, where the most experience is available, low dose effects are still the subject of considerable scientific controversy.

PROCESS OF STANDARDS SETTING FROM HEALTH TESTING DATA

Since standards to reduce or eliminate exposure to toxic chemicals are influenced by many factors, this subject was a matter of some concern during the hearings. For example, Mr. Busterud emphasized the need for a better link between the significance of animal data as applied to human effects. Dr. Warren Muir, also of the Council on Environmental Quality, emphasized the need to arouse public consciousness about the danger from pollutants when they are identified. Such an awareness would create a better environment for planning for social and economic disruptions which sometimes accompany the promulgation of standards.

As others in the hearings pointed out, there is little choice at the present time about the development of many standards from animal data alone. Even though there are many uncertainties about such extrapolations, sufficient animal data can permit formulation of a reasonable estimate of risk to support the development of standards. In this regard, Dr. Sinclair suggested that a thorough study of the standard settings process within the several Federal agencies might be a very useful contribution. As he pointed out, standards setting should involve scientific, legal, political, consumer advocacy, economic, and possibly other viewpoints. An examination of the way that these various inputs are coordinated and the role that each contribution plays in the process could be very useful in assisting the Environmental Protection Agency in developing new standards. Such a review might also serve a useful purpose by "standardizing" the process within other regulatory agencies and thus reduce the complexity of public involvement in and acceptance of new standards in the various areas of regulation.

Dr. Weinberg focused on this issue by pointing out that it is difficult to establish a public policy in the form of a standard for a problem that is currently unanswerable because the data on low level effects just aren't available with total assurance. Certainly, in such circumstances, science alone cannot provide the sole basis for the standards setting decision. He identifies these kinds of problems as "trans-scientific" questions. One approach which he suggested is similar to the development of radiation standards, that is, to establish a standard on the basis of normal background exposure, introduce a factor of safety, and then set the standard at some level no greater than one standard deviation from the normal exposure. Such an approach might be reasonable where pollutants occur naturally and the effect of man's activity is to add to the burden. But even this approach does not adequately solve the problem for those substances which do not occur naturally, as with the many synthetic compounds being introduced into the environment. He also suggested that even where there is reasonable evidence to support the setting of a standard which will provide an acceptable level of protection, it will still be necessary to devote resources to control any adverse side effects

which may still occur. In other words, even effective prevention must still be accompanied by programs which will provide for care and treatment.

In general, Dr. Albert believes that whatever the circumstances associated with the setting of any standard the process must be considered to be dynamic. That is, once estimates of dosages/health effects permit the development of a standard, the effect of the standard must be continuously monitored and changes made to permit the greatest social good to be derived from the standard setting action. Such an approach requires long term programs of monitoring and collection and analysis of data for maximum effectiveness.

PLACE OF EPIDEMIOLOGICAL STUDIES

Examination of the potential of epidemiological studies for the determination of cause/effect relationships of low levels of pollution received a great deal of attention during the hearings. The long time required to complete such studies and the difficulty of getting such long term commitments from good researchers were cited as particular difficulties despite general recognition of the potential value of such studies. Although no specific recommendations were discussed, it was suggested that there is a need for some type of imaginative program to secure an expansion of studies in these areas.

One innovative approach being developed in EPA was referred to by Dr. Albert. He discussed the use of mobile units which provide the capability to move to various sites and to collect both environmental data and population effects data. This type of approach should improve the analysis of health effects through epidemiological studies by providing better control over the collection of such data. One major problem with current studies is that health effects data are frequently collected in an entirely separate spatial and time relationship from that of the collection of pollution data. Thus, correlation of these factors is made much more difficult and although complex statistical analytical techniques can increase to some degree the credibility of such studies, it is essential that exposure and effects be measured as congruently as possible. Frequent reference was made during the hearings to the great value of the most recently published studies by the National Cancer Institute and to the need to follow up in areas of high cancer incidence to attempt to determine any environmental relationships between the cancers observed historically and the exposures to toxic substances in these areas.

In general, adequate epidemiological data are lacking. Although the preferred method of control is to prevent the disease rather than to react to the health effect after the fact, there is little doubt from the discussions presented that there must be a continuation of the epidemiological approach in combination with other efforts to gain knowledge about the effects of toxic substances. This is particularly true since the latency period, that is the time lag between exposure and the appearance of effect, often conceals an incident until it appears in a large population. The diversity of sensitivity within human populations also produces situations where particular subgroups may be more susceptible to toxic effects than the main portion.

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Epidemiological studies can assist in identifying these particularly susceptible sub-groups and possibly permit the development of special protective measures not feasible by the promulgation of standards alone. Epidemiological studies also can contribute to the ongoing analysis of the effectiveness of already promulgated standards and thereby permit the completion of the dynamic analysis of standards which has been cited as a necessary part of the regulatory process. With regard to the dramatic results of the recent National Cancer Institute study, Dr. Marvin Schneiderman believes that the Institute should now be moving to a period of intensive follow-up investigations with emphasis on the "hot spots" of cancer incidence. One difficulty unearthed in this study was the fact that State Health departments are not reporting occupational compensation in a fashion which permits support of epidemiological studies. Other comments indicate that a similar criticism could be leveled at Federal statistics gathering efforts. When questioned about the adequacy of resources to complete such studies, Dr. Muir indicated his belief that even full coordination of all currently available State, Federal and private groups would not provide adequate resources for the types of studies now required.

An encouraging note was evident in the discussion of the new Dow Chemical Company study in Texas. This industry has initiated a program of employee medical examination which should permit the gathering of data over the entire period of employment. It is hoped that this kind of effort will permit the early detection of any adverse effects before serious damage occurs. In this way, employees in situations which are not known to be dangerous could be afforded early protection and the unexpected dangerous situation, if any, modified to prevent further danger.

RISK/BENEFIT ANALYSIS

Dr. Lester Lave, Professor of Economics, Carnegie-Mellon University cautioned that risk/benefit analysis is only one tool to add to the decision making process during the development and implementation of standards. The development of such analyses will only be as accurate as the assumptions made in measuring the value of risks and benefits. As Dr. Lave emphasized, the estimation of the magnitude of an effect is not an easy task. In his opinion, attempts to "monetize" this estimation generally seem to tend towards overestimating costs and underestimating benefits. Dr. Lave was somewhat critical of the EPA estimates of benefits; however, he doesn't feel that such errors really make a significant difference at this state of capability of constructing such analyses because the health benefits to be derived from pollution control far outweigh the error factors which he believes are present in such estimates. As a generalization, he believes that life expectancy will be more favorably influenced by abatement of air pollution, for example, than has been effected by medical care alone in the last 30 years.

Of critical importance to analysis of costs and benefits from pollution control measures is the need to develop more accurate data on health benefits to be expected. Associated with such evaluations is the problem of separating more accurately the amount of a pollutant de-

riving from natural processes not readily amenable to control from the amounts contributed by man's activities. He seemed quite concerned that EPA is not doing enough to provide an adequate data base for making the cost estimates needed for policy discussions.

As Dr. Richmond added, analysts in this field are literally groping for information on the number of people affected by a particular pollutant. Such analysts are only now learning how to assess these problems and there is a need to use ingenuity and all available resources to secure more accurate data on all factors essential to such determinations. The problem is particularly critical because significant errors in such evaluations could lead to wasteful use of limited resources.

Dr. Rall seemed very concerned that there are no reliable estimates of the total costs of pollution, even though there is general agreement that the total costs are quite high. Estimates in 1970, for example, indicated costs in excess of $38 billion. He urged the use of a "holistic" approach in risk/benefit analysis before new or substitute materials are adopted for general use. In order for such analyses to be completed, basic biological effects of new compounds must be known. However, as Dr. Burger states, R&D on bioeffects generally lags the technological development of new compounds; this places the regulator in a reactive rather than an anticipatory position.

AGENCY STRUCTURE FOR SOLVING HEALTH EFFECTS PROBLEMS

Dr. Albert acknowledged in his discussion that there could be much more interaction of EPA with other agencies concerned with protecting the public health from the effects of toxic substances. He suggested that this area of coordination is probably one of the more productive areas to explore since it has a significant impact on gaining rapid and effective input to the solution of regulatory problems. Such a coordination effort also is associated with the development of adequate research programs.

In commenting on the question of regulatory agencies being involved in long-term research, Dr. Rall noted that such agencies tend to get involved in the regulatory role as their primary mission and this makes the manager of the agency less conscious of the need for continuous support of long term research. He cited examples where research resources in regulatory agencies are frequently diverted from the research role in order to react to unexpected regulatory crises. He implied that there is a place for both the long term research role and the regulatory role.

Dr. Finklea of the National Institute of Occupation Safety and Health concurred with this need for separate emphasis. Whether or not the solution to the problem is separate agencies as in the NIOSH/OSHA organizational pattern is subject to further evaluation. It would also be possible to manage this problem by two separate sources of funding within one agency, that is, long range R&D clearly targeted and supported with non-transferable funds and a separately funded R&D role directly supportive to the crisis type reaction needed in many regulatory actions. He views the NIOSH/OSHA concept as an organizational pattern which meets these requirements since NIOSH, in addition to its primary research role, can also provide support on short term problems without being diverted from its primary mission.

Dr. Weinberg suggested that there is a lack of institutions of sufficient breadth of view to create a cohesive doctrine out of all of the issues confronting regulatory agencies. He hypothesized the creation of "centers" to maintain cognizance of the whole area of environmental pollution. Some centers would provide the opportunity for a broad overview, in a continuous fashion, of all of the regulatory issues of the several Federal agencies as well as the potential for an integrated examination of the various research programs within not only the regulatory agencies but also the basic research agencies such as the National Institutes of Health.

The implication of all of these discussions was that the existing programs within EPA do not meet all of the criteria considered most desirable for the solution of both research and regulatory (standards setting) actions.

RESEARCH NEEDS

In summary, the several witnesses seemed to be in general agreement on a number of areas of critical research effort. These include:

The need for accurate information on the effects of low levels of pollutants on large populations;

The development of techniques for quickly assessing the effectiveness of standards which have been imposed to control a health-stressing pollutant;

The need to identify the various environmentally induced factors in disease and more accurately classify these factors as to those which can be controlled by standards setting actions, and classes which may require other actions such as education, changes in food processing, or other programs;

A continuation and intensification of the studies of the relationships between animal testing and human health effects;

Completion of a "catalog" of pollutants which cause health effects;

Continuation of efforts to understand low dose effects as correlated with chemical structure of pollutants;

The identification of uniquely sensitive sub-groups within the human population;

The identification of synergistic effects of pollutants;

Significant improvements in the collection and cataloging of carcinogenic effects (including intensive follow-up of the National Cancer Institute epidemiological studies);

Initiation of programs to follow-up on the cost/benefit analyses estimated for particular standards once these standards are imposed;

A thorough study of the standards setting processes within all regulatory agencies and a correlation of these processes with the applicable legislative requirements;

Consideration of the need for a coordinating agency or center to examine from an overview standpoint, the various interrelated actions of all regulatory agencies involved in control of toxic substances;

More emphasis on improved, more rapid, and less expensive screening tests;

Examination of the factors associated with risk estimating in every standard and development of cohesive standards setting processes related to such philosophies;

A reexamination of the organizational structure of research and development programs within EPA to determine whether funding

restrictions or separation of long term research from the regulatory process is necessary;

Intensification of coordination and clarification of the roles of regulatory agencies and separate research agencies involved in solution of the same problems;

Examination of the need to provide more support for the training of scarce manpower resources such as in the field of epidemiology;

Examination of the relationship between State and Federal research programs as related to epidemiological studies and standards development. For example, there is a well established relationship between State radiation health officers and similar entities at the Federal level; and

Development of a new and shorter process of scientific peer review of research results before political utilization of data exacerbates objective evaluation.

B. Ecosystem Effects of Low-Level Pollutants

Two witnesses addressed the ecosystem effects of low-level environmental pollutants: Dr. Louise Stickel, Director, Patuxent Wildlife Research Center, focused on fish and wildlife effects, while Dr. Patrick I. Coyne, Lawrence Livermore Laboratory, focused on plants. Both observe that the current state of knowledge is totally inadequate to assess the ecological and economic consequences of low-level pollution, but both note that incidents of adverse effects—such as eggshell thinning and reproductive failures because of DDT residues—prove the threat posed by low-level environmental contaminants.

A number of difficulties impede testing for ecosystem effects. First, there are very great interspecies variations. Dr. Stickel cautions against generalizing among species; Dr. Coyne notes that most research on plants have been done on conifers and on agricultural species, and while much of the information may be applicable to natural ecosystems, this needs experimental validation. Second, an organism is seldom exposed to one pollutant, so interactions, which may or may not be additive must be taken into account. Third, pollution is but one stress among many affecting plants, fish, and wildlife, and the role of the pollutant itself may be minor or it may be significant in changing an organism's response to other stresses.

Methods of testing for chronic effects are not well-developed. Dr. Coyne emphasizes the need for more rapid methods of evaluating chronic injury, since waiting for morbidity may, in the case of stress especially, be a matter of many years. In looking at fish and wildlife, Dr. Stickel says that the dose-response concept has proven valid in understanding the effects of low-level exposures on reproduction and eggshell thinning as well as in the effects of high-level exposure on mortality; but she declined to comment on whether this concept holds for carcinogenic or mutagenic effects, saying these effects were outside her area of expertise. She doubts the advisability of trying to predict the effects of low-level exposure from short-term high-level studies, and calls for long and thorough tests at realistically low dosages on species of concern or closely related ones. However, she notes that tests to determine response curves and to assess effects of realistically low dosages are very costly and time consuming—beyond the resources of

many institutions—and subtle effects may be lost in background variability.

Although the measurement and prediction of effects of low-level pollutants can—and must—be improved, the complexity of the world's ecosystem and the costs of testing preclude the ability to anticipate all problems. To a large extent, assessment will depend on essential laboratory experiments, observation of selected populations, and modeling of ecosystems. Dr. Coyne points out the great need of verifying the applicability of laboratory experiments in natural situations, as well as better data collection and modeling. Dr. Stickel especially calls for long, realistic breeding studies, and she says we need more information on what chemicals to analyze for and to study, for the environment might contain many dangerous pollutants about which we know little or nothing. She says studies of fish, which are among the best organisms for catching and holding pollutants, are probably one of the best sources of information on environmental contamination.

Quantifying adverse ecosystem effects are extremely difficult. Estimates of pollution-caused losses of forest trees and losses of commercial fish are possible, but other natural ecosystem losses are almost completely unmeasured. Indeed, some form of life may disappear, says Dr. Stickel, without this being observed. Dr. Coyne says, "The current state of knowledge of air pollution impact on natural ecosystems does not permit even a first approximation assessment of the ecologic or economic impact on a regional or national level," and he notes that though considerable experimental work has been done, its applicability to natural situations is largely unknown.

Dr. Stickel goes on to address the problem of how to set standards to protect fish and wildlife. She notes that standards to protect fish and wildlife are usually set on the basis of proof of effects, and she urges that excessive proof should not be required, but normal standards of scientific inference should prevail. Standards should evolve with new knowledge. She says decisions should be made by panels of the best experts, and unqualified persons should not be included just to provide an adversary position or a set of impartial decision-makers. The public should have a say, possibly through the hearings process, and a regulatory or political authority should have the final say.

In conclusion, Dr. Stickel identifies three classes of concern: (1) major known threats, persistent pesticides and PCBs; (2) major potential threats, heavy metals (Hg, Cd, Ph) and petroleum components; and (3) unknown threats, continuously being suggested by new information, and she said better determination of these last is a critical need. She also concludes that more emphasis should be put on finding the point sources of pollutants which may be most controllable.

C. Effects of Chronic Low-Level Air Pollutants on Agriculture

Major Threats

O. Clifton Taylor, Horticulturist and Associate Director, Statewide Air Pollution Research Center, University of California at Riverside testified:

It has been amply demonstrated that current ambient levels of air pollution significantly affect agricultural crops, forests, and natural plant communities. The effects from chronic, low levels of pollutants are less well defined. Because injury symptoms are usually specific for given pollutants, plants occupy the unique position of often being the first indicator that an heretofore unaffected area is being polluted.

Testimony of U.S. Department of Agriculture's Deputy Assistant Secretary, Paul A. Vander Myde, served to amplify Dr. Taylor's statement. The pollutants, he stated, not only reduce yields and quality of crops, but in addition, they affect plant response to disease, insects, and other stress factors, such as drought, nutrient deficiencies and temperature extremes.

Ozone (O_3) is the most important and extensively distributed phytotoxic air pollutant in the United States today, according to Dr. William Manning of the University of Massachusetts' Suburban Experiment Station. The threat of low-levels of O_3 under field conditions, he states, stems from reduction in photosynthesis, acceleration of senescence and early maturity. O_3-injured crops also may be more susceptible to diseases caused by facultative parasitic fungi.

Dr. Taylor emphasized that the threat to the agroecosystem is potentially great in view of relative simplicity of the system. Large areas are devoted to a single crop and often a single variety of a species of that crop. Thus, a single pollution episode can be catastrophic and repeated episodes during a growing season can assure tremendous losses. The trend might be reversible, he stated, and some stability achieved either by a change in crops, cultural practices, or by moving to a less polluted area. The natural ecosystem may adjust to a chronic, low concentration exposures by selection and reproduction of tolerant individuals within a species; however, Taylor stated, this adjustment may not be commensurate with the needs of the present or the next generation.

Although the effects of air pollutants generally are reflected in losses to a grower, Dr. Taylor stressed that hydrogen fluoride is unique in that HF accumulations by leaf tissue can be transferred to animals through forage. This can cause serious disease of bone and teeth and even death to animals.

Dose response, prediction and measurement of danger

Both Taylor and Vander Myde testified that, although considerable information exists on the effects of pollution on plants, quantifying the effects has been less than successful. Extrapolations are difficult because dose response patterns may vary with plant species or cultivar, pollutant and category of response one chooses to measure. Dr. Taylor reported that recent studies of response of alfalfa to ambient ozone levels showed that when foliar injury was measured, the response was curvilinear, however, when yield was measured, the response was linear.

The testimony of Dr. Auerbach, Oak Ridge National Laboratory, stressed that a single pollutant or combination of pollutants with similar characteristics may significantly affect agriculture and the biosphere. Although researchers may define the effects of chronic, low-level pollutant damage, Auerbach states, the ability to assess the relationship is deficient. Each pollutant, listed in Table 1, by virtue of

one or more characteristics may be a major factor interacting at a chronic level.

Dr. Auerbach's catalogue of the effects, probable mechanisms and pollutants involved (Table 2) illustrated the complexity of arriving at a field estimate of dose-response. Photosynthesis, he stressed, is sensitive to a range of pollutants including O_3, SO_2, HF, PAN, and Pb. Because of synergistic interactions, Mr. Vander Myde pointed out, it is not possible to follow a transect from an urban area into a rural area and expect to compare yields with pollutant concentrations. The most feasible approach, he stated, is to use pairs of open-top chambers over field grown crops; one with charcoal-filtered air and the other with ambient air continually flushed through it.

According to Dr. Taylor such studies undertaken in Southern California indicated ambient pollutants reduced yields in Riverside in 1974 for the following crops: alfalfa—38 percent; blackeye beans—32 percent; lettuce—42 percent; sweet corn—72 percent; radish—38 percent; lemons—30 percent; oranges—50 percent; and grapes—60 percent. If these loss rates applied throughout the Los Angeles basin, the basin losses would exceed $10 million, according to Taylor.

Dr. Taylor's testimony included a summary of measurement of air pollution impact on forests and a comparison of yields during polluted and non-polluted years. He succinctly stated:

> Comparison was made of annual ring (radial) growth and height growth between equal numbers of two similar age groups of ponderosa pines in the San Bernardino mountains during 1910–1940 (unpolluted years) and 1944–1974 (polluted years). The results showed that merchantable volume of wood produced (after variability from climate was removed) was 20 board feet from 1910–1940 and 5 board feet from 1944–1974.

In spite of the foregoing measurements, all witnesses appear to concur on the inability to accurately measure and predict agricultural losses from low-level pollutant concentrations. They stress the need for better understanding of (a) the mechanism of action, (b) the mechanism of plant reaction, (c) the capabilities for cell repair, (d) interaction of other stress factors, (e) dose-response, (f) species variability, (g) dispersal and measurement of pollutants.

TABLE 1.—MAJOR POLLUTANTS INDUCING CHRONIC EFFECTS TO VEGETATION

Pollutant	Capable of long-distance transport	Quantitatively significant or widely dispersed	Highly soluble in living tissues	Highly reactive in living tissues	Resistant to metabolic detoxification	Capable of bioaccumulation
SO_2	X	X	X	X		X
SO_4	X	X	X			X
O_3	X	X		X		
NO_x	X	X		X		
PAN	X	X		X		
HF			X		X	X
Pb	X	X	X[1]		X	X
Hg	X	X	X[1]	X[1]	X[1]	X
Cd	X				X	X
As		X		X		

[1] In organic form.

TABLE 2.—TYPES OF CHRONIC LOW-LEVEL EFFECTS AND PROBABLE MECHANISMS INVOLVED

Type of effect and probable mechanisms	Pollutants involved [1]
Reduces growth:	
Decreased photosynthesis	SO_2, O_3, NO_x, HF, PAN, Pb.
Increased respiration	HF, SO_2.
Biochemical changes:	
Enzyme inhibition	SO_2, O_3, PAN, HF, As.
Electron (energy) transport	HF, O_3, PAN.
Effects on photopigments	SO_2, HF, O_3, PAN, NO_x.
Stomatal function	SO_2, O_3.
Membrane permeability	O_3, PAN, SO_2, HF, metals.
Premature senescence of leaves	SO_2, O_2, PAN, NO_2.
Physical changes:	
UV reflectivity	Acid rain.
Heat exchange	Do.
Gas exchange	Do.
Changes in symbiosis	O_3, acid rain.
Effects on nutrient flux	SO_2, acid rain.
Reduced reproduction:	
Reduced carbohydrate availability for reproductive structures	SO_2, O_3, HF, PAN, Pb, NO_2.
Effects on reproductive processes:	
Flower or fruit production	Smog, HF, SO_2.
Pollen germination or tube elongation	SO_2, O_3, HF.
Mutagenesis	SO_2.
Effects on pollinating insects	HF.
Increased morbidity: Inadequate carbohydrate supply to support autotrophic respiration and resist disease. Reduced growth and loss of ability to compete with other vegetation.	SO_2, O_3, HF, PAN, NO_2, heavy metals.

[1] Includes pollutants for which specific effects have been documented and those whose biochemical symptomology strongly implicate them as probable causal agents.

D. The Impact of Chronic Low-Level Pollution on Weather and Climate

At the outset, all witnesses concurred that this was a very complex subject—a subject in which questions and speculations far outnumbered answers, and firm knowledge on many aspects and characteristics was in some cases nonexistent or incomplete, and otherwise tenuous at best. However, the consequences of not recognizing or asking the correct questions or of coming up with incorrect answers may be immeasurably severe. It was also stated that a need exists to distinguish carefully between local, regional, and global effects. Local effects concern areas of a few kilometers. Global effects are, of course, worldwide. The larger the size of the area, the less is known about it.

To almost everyone climate means the average temperature and precipitation of a locality. This is a rather misleading concept, for the average may be a rare event. Actually, weather from year to year oscillates widely so that climate is a statistical complex of many values. Climate also includes atmospheric elements other than temperature and precipitation such as: insolation, cloud cover, visual range, wind and humidity. Equally important are special events including fog, thunderstorms and frost. All these elements are included in climate. Rather than by average value, they are best characterized by frequency distributions, which can, in many places, span a wide range for a given element. Within such a range one notes irregular fluctuations, but even occurence of one or two rather extreme values should not be interpreted as a climatic change. That term should be reserved for events on a geologic timescale encompassing thousands of years. A

change denotes that a new equilibrium exists and with it a rather different frequency distribution for all climatic elements. Thus the term change is not to be confused with "fluctuation," where trends are frequently reversed even though some successive values may cluster for a while on one side or the other of the average.

Chronic low-level pollutants of greatest concern

Despite limitations in knowledge, there is widespread agreement that mankind is on the verge, if not already capable, of being able to emit pollutants in sufficient quantity that may noticeably disturb the delicate atmospheric balances of energy, radiation, and water on a local, regional and, perhaps, global scale. Essentially all act to either disturb the radiation balance or the precipitation mechanism—two processes having fundamental impact in determining climate, according to witnesses.

First, there is the introduction into the atmosphere of gases which have the effect of modifying the natural thermal balance of the atmosphere. These include carbon dioxide which is produced primarily from the burning of fossil fuels, and also the fluorocarbons and oxides of nitrogen or other gases that may either have direct effects themselves or as a result of chemical activity may modify other radiatively important atmospheric constituents such as ozone.

Particles are a second category of pollutants that may be introduced by industrial or agricultural practices. They have potential climatic effects through control of atmospheric heat balance.

A third category is the direct introduction of heat into the atmosphere as a result of all forms of energy production and consumption. While this is not a current problem of global concern, it should nevertheless be recognized for its potential future impact.

The altered chemical nature of precipitation is a fourth category of pollution. While this may not be a climatic influence in the usual sense, it does have important ecological consequences that appear to be of more than strictly local character, according to testimony at the hearings.

Carbon Dioxide.—If there is any single substance produced by man that is likely to give rise to climatic variations, it is carbon dioxide. But even in this case, the specific effects cannot now be determined with any certainty. This gas, which is a natural constitutent of the atmosphere, has monotonically increased over the past 100 years in conjunction with the rapidly rising consumption of fossil fuels (coal, oil, natural gas). Carbon dioxide affects climate by absorbing and reemitting terrestrial outgoing long-wave radiation. Carbon dioxide does not attentuate the incoming short-wave radiation from the sun. This warming effect on the lower atmosphere is often referred to as the "greenhouse effect."

The interception of outgoing radiation from the earth has been interpreted as leading to global warming. However, in the absence of knowledge of all possible feedback mechanisms of the atmosphere/ocean/ice system that controls weather and climate, the extent of such warming cannot be predicted with complete confidence. There are some reasons to believe that this would be a self-limiting process. Recent calculations of the National Oceanic and Atmospheric Administration argue for a 2.9 degree Celsius (5.3 degree Fahrenheit) warming

averaged over the globe in response to a doubling of the concentration of carbon dioxide.

In spite of these uncertainties, though, one thing is clear: Given a substantial increase in the concentration of carbon dioxide, even if the global average temperature conditions were not to change markedly, the new balance that would be achieved would involve a somewhat different set of constraints, and there would almost certainly be noticeable regional climatic changes.

It was also stated that the possible effects of various pollutants, such as oxides of nitrogen or chlorofluoromethanes, on the stratospheric ozone layer would have only minimal influence on surface climate. While it was agreed that the problem warrants further attention, the conclusion was that the climatic effects of ozone reduction that might result from chlorofluoromethanes is not as serious and immediate a problem as the potential increased exposure to ultraviolet radiation at the surface.

Particle Loading.—Small particles in the atmosphere can influence climate in ways quite similar to those of the radiatively active gases, but the problems here are even more complex than with gaseous pollution. On the one hand, the partitioning of the sources of particles in the atmosphere between man and nature is subject to both doubt and controversy. Even though estimates of the total man-made output of particulate aerosols is not exactly known, most estimates place it between 10 and 30 percent of the natural aerosol production.

Sources of particulate emissions include man-made fires, industrial activtites, combustion of fuels in autos and power plants, and agriculture. Even more significant may be natural substances such as dust from volcanic eruptions, sea salt from evaporated ocean spray, smoke from lightning-caused forest fires, debris from meteors which burn up in the atmosphere, wind-blown dust or sand storms, and organic compounds emitted by vegetation.

Unlike the situation with regard to carbon dioxide, there is uncertainty as to whether the concentration of particles in the atmosphere is actually growing. Fortunately, the residence time of aerosols in the near-surface atmosphere is very short, and, in fact, measured in days. Only in dry regions may it last a few weeks. There is no evidence of any long-term accumulation of low-level aerosols on a global scale. Fall-out and wash-out cleanse most of them. Aerosols that are introduced into the stratosphere have much longer residence times; therefore, restrictions on these emissions may be in order to prevent possible alterations of climate.

There is a dispute as to whether more particles mean a warming or cooling of the lower atmosphere. Indeed the situation is such that depending upon the nature of the particles, and where in the atmosphere they are found, particles may induce either cooling or warming.

Thermal pollution.—Another man-generated pollutant that could affect the weather and climate is waste heat generated by combustion, automobiles, home heating, industrial processes and power generation—all produce heat that eventually is emitted into the atmosphere. In addition to its direct effect on atmospheric temperature, in specific situations waste heat can enhance convection, the vertical motion so important in precipitation processes, according to testimony.

On a local scale, the climatic effects of energy use and heat production are significant and well documented. Urban areas experience thermal effects and have been frequently referred to as "urban heat islands." On a regional scale, thermal effects may become important by the turn of the century. However, on a global scale, climatic effects of thermal pollution today and for the near future appear to be insignificant.

Altered chemical nature of precipitation.—Another byproduct of air pollution is the acidification of precipitation. Although scavenging of pollutants by rain is a welcomed self-cleansing process of the atmosphere, some of the substances thus removed acidify the precipitation. Oxides of sulfur and nitrogen are the ultimate sources of most of the atmospheric acids. There are ecological consequences associated with this growing acidification of precipitation, which is suspected of damaging lakes, agriculture, and forests, according to testimony.

Although the emphasis heretofore has been concerned with effects on the global scale, local scale effects should not be overlooked. Pollutants in urban and industrialized areas have measurable and substantial influence on various climatic elements. Reduced sunshine and restrictions on visual range have been observed. There exist notable increases in fog. Influences on cloud and precipitation processes have been noted. The enormous production of condensation nuclei by human activities measurably affects the number and size distribution of cloud droplets and, depending on circumstances, can inhibit or enhance precipitation. Some anthropogenic substances may also act as cloud seeding agents and, especially in winter time, can initiate precipitation. Available information indicates that these effects are reversible and improvements have occurred where pollution controls have been instituted and enforced.

Table 1 summarizes these and other chronic low-level pollutants in terms of observed trends, potential atmospheric effect, status of assessment capability, and time scale of importance.

Measuring climatic effects

The first problem in measuring the effects of perturbations on the climatic system is defining what is meant by the term natural climate (i.e., average conditions). Average conditions over millenia are not important right now; yet if climate is defined over too short a time, large fluctuations and variability could obscure any slow and steady trend. A period on the order of several decades appears a useful compromise.

Using this time scale, there is a requirement for spatially representative, accurate but diverse kinds of data. This, in turn, poses difficulties in terms of data station location and instrumentation.

What needs to be determined is just how much of a climatic change or fluctuation is attributable to a change in global energy balance and how much is attributable to a change in the distribution of energy (i.e. a longitudinal shifting of weather patterns rather than a change in them). This capability is vital if forecasting future climates and assessing the potential impact of man's activities are goals.

Resolving such matters requires extensive data, not just from the present (by satellites, aircraft, and ground stations), but also based

on reconstructions of past climates (e.g. from tree rings, ocean sediment records, isotopic analysis, etc.).

Predicting climatic effects

Because natural processes affecting the delicately balanced climatic system are not yet fully understood, there are limitations as to what conclusions may be drawn about how man's effluents may affect climate. Many processes interact and feed back to produce measurable effects; natural processes may amplify the effects of perturbations.

Nearly all models exclude some of the important processes, both for simplicity and for lack of understanding. Whether the remaining processes which are included constitute an adequate set could likely only be proven by constructing as comprehensive a climate model as possible and then simplifying from that model. Research and especially computer capabilities have not yet achieved this goal. A hierarchy of modeling and analytical approaches was recommended as an assured program for better understanding climate and its fluctuation and change.

TABLE 3.—CHRONIC LOW-LEVEL POLLUTANTS

Pollutant and source	Observed trend	Potential atmospheric effect	Status of assessment capability	Time scale of importance
Carbon dioxide (CO_2) from combustion of fossil fuels.	Up more than 20 percent in last 100 yrs.	Increased global temperatures leading to melting of polar icecaps, sea level increase, perturbations of marine biology.	Numerical model assessments of the global average effect on temperature differ by about a factor of 2; consequence chains need more study.	Thorough assessment needed in the next 5 yrs—may be a problem over next 50 yrs.
Fluorocarbons (e.g., freon) from aerosol cans, refrigeration systems, etc. Nitrogen oxides from high flying aircraft (and perhaps from fertilizers).	Fluorocarbons are now detectable throughout the atmosphere. Nitrogen oxides are a natural component. Stratospheric measurement program being established to determine levels and trends.	Reductions of the global stratospheric ozone layer and perturbation of the atmosphere's radiation balance. Analysis of current trend in ozone is not yet definitive due to natural variability.	Numerical models are capable of assessing the order of magnitude of the various effects, with uncertainties related to lack of basic information on reactions, and reaction rates; the natural chlorine and nitrogen balance; and the limitations in simulating simultaneously global chemistry, transport, seasonal, and diurnal processes.	Initial assessment in progress by National Academy of Sciences—action probably needed within several years.
Krypton-85 from nuclear fuel reprocessing and powerplants.	Building up proportionally with nuclear power generation.	Modification of the atmosphere's electric field, which may cause modification of the hydrologic cycle.	Not adequate.	Thorough assessment needed, may be a problem over next 100 yrs with growth of nuclear power industry.
Sulfur compounds from fossil fuel combustion.	Not well-established, but concentrations may already be too high on occasion.	May affect regional precipitation chemistry and acidity on regional to subcontinental scale.	Sulfur balance not well understood.	May presently be a problem which would be aggrevated by further coal burning.
Dust from combustion, slash/burn agriculture, and improper land conservation.	Not well-established because of evolution of sources and particles sizes with controls.	Initial response is temperature change (sign dependent on location and source type), precipitation modification. Problem mainly on subcontinental, but possibly up to global scale.	Theoretical capability is improving, but inadequate knowledge of both trends and consequences exists.	Further evaluation needed as improved data available.

TABLE 3.—CHRONIC LOW-LEVEL POLLUTANTS—Continued

Pollutant and source	Observed trend	Potential atmospheric effect	Status of assessment capability	Time scale of importance
Heat and water releases to the atmosphere from the energy generation process (thermal pollution, cooling towers, etc.).	Increasing with energy generation.	Temperature and precipitation modification on local and regional scale.	Models of atmospheric boundary layer are being developed.	Evaluation needed in regions of concentrated energy generation (e.g., energy parks, etc.).
Oceanic oil slicks from tanker cleaning, etc.	Not known.	By changing the reflectivity and evaporation characteristics of large oceanic areas, the Earth's energy balance might be perturbed in an unknown way.	Further research needed.	Assessment needed as capability for evaluation improves.

Standard setting

Of direct concern are questions of standards for atmospheric measurements. Consistently calibrated instruments and uniform data collection standards are essential to the development of a solid basis for air quality standards for chronic low-level pollution. Because of limited and often inadequate knowledge of climatic effects, trace level pollution standard setting will have to be done carefully and approached cautiously. Because methodologies available for evaluation will change, the standards must not only be carefully considered initially, but will be susceptible to later reconsideration or continual reconfirmation at periodic intervals based on facts, probabilities and conscious value judgments.

International comparisons of atmospheric sensors through the United Nations World Meteorological Organization should continue. Furthermore, firm international agreement regarding measured levels of pollution, as well as international agreement on the scientific and practical implications of measured levels are necessary prerequisites to achieving international agreement on standards, according to the experts.

Recommendations

Neglecting to promote climatological research has given rise to far more questions than answers. Many avenues need to be pursued, some of which have already been mentioned. These and others are listed below:

Measurements of sun-to-earth and earth-to-space energy exchanges;

Further development of three-dimensional atmosphere-ocean climatic models and provision of computer capacity to handle them;

Extension of the global climatic surface network to areas where coverage is currently inadequate, with centralized collection and analysis of the observations on a current basis;

Support of the climatological program goals of the U.N.-sponsored Global Atmospheric Research Program as well as the goals and objectives of other international environmental programs, among them: the Integrated Global Ocean Station System (IGOSS); EARTHWATCH and the Global Environment Monitoring System, both

major components of the United Nations Environment Program (UNEP); and the Global Observing System (GOS). The importance of planning, developing, and implementing global baseline and regional monitoring programs which endeavor to obtain worldwide measurements of the interacting air, sea, ice and land components of the global climate system cannot be overemphasized;

Monitoring of pollutants with potential influence on climate, soils and water at a sufficient number of sites and in the vertical dimension. Utilizing geosynchronous and polar-orbiting satellites, aircraft, ships, buoys, platforms, and balloons, along with conventional surface-based observations of the atmosphere, ocean, ice masses, and exposed land surface, data will be obtained that more adequately describe the mechanics of the global climate machine and its response to trace level pollutants; and

Studies of climatic elements downwind of major urban centers and power complexes to ascertain the areal extent of the atmospheric influence of this type of human activity.

VIII.—SUMMARY OF STATEMENTS RECEIVED FROM PROFESSIONAL SOCIETIES, UNIVERSITIES AND OTHER GROUPS

As a part of the record for the hearings, the Subcommittee solicited contributions from a wide variety of professional societies and other groups. The goal was to broaden the information base of the normal Congressional hearing procedure, and to bring the best and most timely scientific thinking and information available into the political decision making process. By inviting the respondents to use any convenient working method—task forces, questionnaires, review panels, collecting individual scientists' statements, etc.—the Subcommittee hoped to set up a model for rapid, informal input of professional society and other expertise in questions of public policy.

The response was excellent. Thirty professional societies and seven other groups contributed well-reasoned and documented papers on a variety of aspects of the hearing outline. The material far transcended, in depth and policy impact, what could possibly have been obtained in ordinary hearing proceedings. Much of the material was not only reviewed but also generated by the most authoritative leaders in the fields of health, agriculture and meteorology, and thus represents the highest consensus of scientific opinion as to critical problems in this area.

Following is the letter of request from Chairman Brown to the outside groups, which was accompanied by the hearing outline.

COMMITTEE ON SCIENCE AND TECHNOLOGY,
U.S. HOUSE OF REPRESENTATIVES,
Washington, D.C., August 1, 1975.

Dear—:

The Subcommittee on the Environment and the Atmosphere of the House Committee on Science and Technology plans to hold hearings late in the current session of Congress on the costs and effects of chronic, low-level environmental pollution. We will consider the state of knowledge in the areas of health, agriculture, climate effects, and other aspects of the biosphere. Our goals will be to assess the research needs in these areas, and how the state of knowledge relates to the nation's ability to set reasonable environmental standards.

The Subcommittee has legislative jurisdiction over the Federal government's environmental research and development activities, and we want very much to make sure that programs and budgets are correctly taking into account needs in this field. In other words, we want to establish for the record the relationship of knowledge or gaps of knowledge in this area to the judgments that must be made in standard setting.

We intend to invite a cross-section of experts to testify at these hearings. The time for oral presentations is inevitably limited, however, and since witnesses who appear normally provide only a portion of the information needed to establish policy, it is our practice to invite others to submit statements for the record. We would like, therefore, to invite your group to contribute a written statement if you feel that you have an important point of view to present. A tentative outline of the hearings is enclosed. We hope you will focus on the questions which

are within your special area of competence, as well as raise others you feel may have been overlooked.

We invite your comments not only on research needs, but also on the priorities and relative prospects for progress among them. We hope to identify the areas of research investment which have the potential for greatest contribution to rationalizing standard setting.

Standard setting to protect man is the first concern of Federal environmental research, and we want to view current and proposed efforts by how effectively they contribute to that goal.

I can't overemphasize how important to our deliberations are the views of independent experts like those you represent. Our Committee becomes involved in extremely technical areas, and unless we have access to the full range of technical judgment in this country, we will not be able to deal with critical problems as wisely as we should. I would also have greater faith in my Subcommittee's future actions if the submission of a written statement were only the beginning of a continuing exchange of ideas with your group. I would hope, in fact, that our hearings would establish the basis for an informal working relationship with you in the area of environmental effects.

Please feel free to contact Dr. Thomas Moss of my office on any questions you may need to discuss. We would hope to receive your statement by October 15.

Let me thank you in advance for your contribution to public policy in this area, and I look forward to working with you.

Very truly yours,

George E. Brown, Jr.
Chairman, Subcommittee on the Environment and the Atmosphere.

SUMMARY OF SOCIETY CONTRIBUTIONS

(1) *Assessing the effects of pollution in the chronic, low-level range is indeed a dangerously neglected area.*—Though contributors from almost all areas—health, agriculture, general ecology, and meteorology—agreed on the possible enormous costs and complexities of chronic effects, most observed that the resources seemed to be inevitably directed toward short term crises. The summary of the interdisciplinary contribution from more than eighteen individuals in the University of California, stated that "a common theme running through all of the responses is a recognition that levels of uncertainty regarding low-level pollutants are extremely high, and that research programs are very often not targeted towards resolving these uncertainties."

(2) *Lack of coordination among Federal agencies in this inherently interdisciplinary area has made solid research progress almost impossible.*—The American Society of Agronomy stressed, "We in Agriculture have been frustrated by the lack of sufficient research in the Health Effects Branch of EPA. We find the environmental health research effort is too small and is fragmented among, EPA, NIH, and FDA." The American Fisheries Society similarly emphasized that "there is a great need to improve communication between scientists, regulatory groups, industry, and the general public on matters concerning health and the environment. The present structure of many regulatory groups responsible for various phases of environmental and health protection is causing confusion and frustration in the general public."

(3) *Monitoring of base-line and perturbed human, agricultural and biosphere health is essential to reaching an understanding of environmental pollutant threats to health in all these areas.*—As a top priority recommendation, the American Phytopathological Society wrote, "To obtain information needed for revision of standards, data on pollutant concentrations . . . need to be obtained. Combined pollutant monitoring with instruments and plants should be done at strategic locations all over the country as a continuous check on the effectiveness of pollutant standards." Similar considerations apply to substances which may affect the total biosphere through effects on climate. An American Meteorological Society Committee emphasized that "it is essential that the global distribution of various trace chemical species in the stratosphere and troposphere be measured, monitored, and interpreted." And in human health itself, the American Society of Biological Chemists stressed that exposures to chemicals are so pervasive, and traditional cause-effect diagnoses of pollutant-caused disease are

so ineffective in the chronic realm, that careful statistical analyses of health trends are essential to help us see the dangers we are inflicting on ourselves.

(4) *Transport, transformation and synergistic effects of trace pollutants may be the key to our understanding of their effects, and yet our research has tended to focus on their properties at the source of emission and in isolation from each other.*—The A.D. Little Corporation, submitting a statement on behalf of Kennecott Copper, Phelps Dodge, and the Electric Power Research Institute, stressed that all health effects attributed to SO_2 emissions may actually be due to effects of SO_2 combined with other pollutants. The problems of widespread transport and dangerous transformation of pollutants was emphasized by the Society of American Foresters: "there is legitimate concern that limits of ambient pollution in local areas leads toward 'tall stack' solutions that only tend to distribute the problem of chronic pollution and acidic precipitation over ever-widening zones.—And there is need to avoid mere cosmetic emission control of particulates, at the expense of creating more invisibles that result in chronic air pollution and acid rains."

(5) *In some cases totally verifiable cause-and-effect evidence for harm due to chronic pollution may be impossible to obtain; even though the potential danger is very great.*—In these cases, several groups recommended that standard setting be based on probability of risk, rather than "proof-of-effect." The American Medical Association, citing the difficulties in obtaining epidemiological evidence and the long time span required, stressed that, "Ideally, the basis of standards should move from proven effects to probabilities of risk. To do this, the nation will have to improve its capabilities to evaluate the probability of risk." Similarly, in the field of forestry, "There is concern in the forestry community that a shift toward 'proof-of-effects assessments' as a basis for emission control is short-sighted and could be disastrous to forest ecosystems where we cannot make adequate estimates of pollution impacts and where the effects might not become evident until long after emissions have begun."

(6) *The research needed to answer the critical questions of effects of chronic pollutants must be of a long-term, steadily sustained, nature.*—Because chronic pollution effects are inherently so complicated to assess, "crash programs" of strictly targeted research are not likely to be helpful. The American Society for Microbiology stressed the need to avoid crisis research, and that "better research and more data are needed to fill the gaps, on which to base new standards, and on which to make predictions." The Institute of Ecology sent the Subcommittee's questionnaire to 220 of its members, with more than 50 responses received. One of the strongest points made by the respondees was the following: "One of the most important (needed) changes involves the time-frame of research, monitoring and control activities. When we are dealing with chronic effects which may take decades to make their magnitude fully apparent, we must move beyond fiscal plans based on a two year cycle."

In the specfic areas, starting with human health, the following needs were cited by numerous societies:

(1) Epidemiological studies need to be sharply expanded, better designed, and efforts of Federal state county and local agencies need to be much better coordinated in order to obtain a true picture of pollutant threats to health. The American Medical Association wrote that, "there is no other way (than epidemiology) to obtain the needed dose-response or exposure-response relationships between complex urban atmospheres and specific health effects."

(2) General screening of mass produced chemicals for mutagenic and carcinogenic effects should be started at once. Numerous societies pointed out that rapid and inexpensive bacterial screening tests could be used as a preliminary alert of possible genetic effects of chemicals produced in large volumes, with more extensive animal testing to be used as a follow-up in suspicious cases.

(3) Trained manpower in epidemiology and public environmental health is in short supply. Traditional medical curricula do not emphasize the statistical aspects of public health which are so important in evaluating environmental health threats.

In the areas of agriculture, the following points were most strongly made:

(1) The agricultural and forestry groups agreed that large-scale damage to productivity is occurring at pollutant concentrations much below ambient standards or commonly observed ambient levels. Moreover, damage is widespread and often not related to proximity to sources of pollutant emissions.

(2) Research is most urgently needed in assessing the costs in agricultural productivity due to pollutants. This is especially critical as we move out of an era of agricultural surpluses, and is essential in striking proper cost-benefit balances in standard setting.

(3) In a particular area, that of using sewage sludge as fertilizer for agricultural land, lack of information is causing confusion among both farmers and sewage authorities. The disposal of sewage sludge as a soil conditioner or fertilizer may be essential to the successful economics of some sewage treatment systems, but the conditions of safety of this procedure on land used for food crops is not established, and current research programs are not addressing the problem sufficiently.

In the area of possible climate effects due to chronic pollution, these two points were stressed:

(1) The costs of even small climate changes could be enormous, in terms of agricultural productivity alone. For this reason investment in global monitoring systems of climate trends, and of man-made or natural changes in the atmosphere components, could have a very high return in terms of critically needed data.

(2) In particular, there is near unanimity that the carbon dioxide concentration in the atmosphere is increasing rapidly and in 2050 will be double its 1800 level. Though even the direction (warming or cooling) of the climate change to be caused by this change is unknown, very profound changes in the balance of climate factors that determine temperature and rainfall on the earth might occur within 100 years. Monitoring programs started now, before the carbon dioxide effect begins to be substantial, could provide essential warnings of needed changes in human activity before disastrous effects occur.

IX.—SUMMARY OF THE LIBRARY OF CONGRESS STUDY

In addition to the hearing record, the Subcommittee requested that the Library of Congress do an interdisciplinary study of the state of knowledge and issues relating to chronic exposure to low-level pollution. The study, completed just prior to the hearings, provided excellent background and preparation for them. Following is the letter of request from Chairman Brown to the Congressional Research Service, outlining the need for the study, and a summary of the main points of the study itself:

CONGRESS OF THE UNITED STATES,
HOUSE OF REPRESENTATIVES,
Washington, D.C., July 3, 1975.

MR. LESTER JAYSON,
Director, Congressional Research Service,
Library of Congress, Washington, D.C.

DEAR MR. JAYSON: The Subcommittee on Environment and the Atmosphere, which I chair, will be holding hearings in the fall on effects of chronic, low-levels of environmental pollution—on health, agriculture, climate, and the biosphere as a whole. Part of the aim will be to raise the state of Congressional and public awareness about how little we know in the area of long-term, chronic pollution effects, even compared to our relatively shaky knowledge of the consequences of various acute exposures. Much more importantly, however, we would like to determine the relation of the state of knowledge in this realm to the needs of standard setting. Specifically, we will want to focus on what changes in the emphasis or organization of environmental research would be helpful in providing a more effective scientific, legal, and political basis for standard setting relative to chronic pollution effects.

I would like to request the assistance of the Congressional Research Service in this effort, starting with a group of four committee prints designed to set the stage for the hearings. A discussion outline of what could be appropriate is attached. At this stage I mean this outline only to be taken as representing our current thinking—we will want to get the reactions of your experts and combine those with our approach to get the final definition of the project. Dr. Thomas Moss of my staff, and Dr. Rad Byerly of Committee staff, are prepared to work closely and continually with your researchers to make sure that the project is manageable and meets our needs without any wasteful and unnecessary work on your part. I should note that though the attached outline seems very comprehensive, we are most interested now in pulling together the best existing perceptions of knowledge and problems in these areas, rather than asking for an in-depth analysis of them. At this point we want mainly to document the state of the art, rather than attempt to greatly advance it. I would hope that this would make the task of following an outline like this somewhat more finite. Moreover, the outline is meant to be general enough to include all four areas of emphasis, which means some of the points will not be appropriate for any one of them.

I would like to make one particular request about your approach, however, and that is that it be a strongly interdisciplinary effort within CRS. For instance, though this is primarily an "environmental" topic, we are extremely interested in what the implications of recent legal decisions (Reserve Mining case, reversal of EPA's regulations on lead in gasoline) are for environmental research. We would hope, then, that your experts in legal, medical and other fields would be strongly involved in the project as well as your environmental group.

I would hope you could begin this work immediately, so that there will be time to do a thorough job before September. It might be helpful if Dr. Moss and Dr. Byerly could meet soon with the coordinating staff member you designate,

in order to begin discussions on the best approach. I will ask Dr. Moss to be in contact with your office to set up a meeting.

Thank you in advance for your cooperation, and I will look forward to working closely with you on this project. I think it can be an extremely important service to the Congress, and could help us take a big step in an important but rather neglected area.

Very truly yours,

George E. Brown, Jr.

Highlights of Congressional Research Service Study

In the case of health effects, the study found

(1) With control of major infectious diseases nearly complete, chronic pollution induced damage to human health has become one of our most serious medical problems. There is general recognition, for instance, that the great majority of all human cancer is triggered by exposure to hazardous substances in the environment.

(2) Our abilities even to correctly diagnose chemically induced health effects are so limited that we probably only recognize a small portion of the damage. The study quoted Nobel Laureate Joshua Lederberg's observation that "if the malformation induced by thalidomide were a mental retardation of 10 percent of I.Q. instead of a highly characteristic and unusual deformation of the limbs, in an equal number of subjects, we would be unaware of it to this day."

(3) The costs to society of environmental pollutant linked disease are staggering. The costs of cancer alone are estimated at 11 billion dollars per year, of which 70 to 90 percent may be environmentally related. But cancer just happens to be relatively easily recognized; there may be chronic respiratory and neurological, as well as genetic effects, with even greater economic costs.

(4) Our current testing methods, while often arduous and expensive, are not sufficiently sensitive to detect effects of agents which might cause as many as hundreds of deaths annually, or even far greater numbers of sublethal debilitating effects or future genetic harm.

(5) The significance and costs of environmental pollutant caused disease has not been reflected in Federal research emphasis. Only about 10% of the budget of the National cancer program has gone into environmental chemical carcinogenesis, despite concensus on this as a causal factor.

(6) Because the effects of chronic pollutant induced health damage are so different from the acute problems of infectious disease and injury with which we are more familiar, traditional legal concepts of showing cause and effect are proving inapplicable to the justification of standard setting in the chronic exposure domain. The legal and scientific controversy over the Reserve Mining case and the case of Ethyl Corporation vs. EPA (phase out of lead in gasoline) show that a better match is needed between the nature of research results in chronic pollution effects, and standard setting methodology.

In the areas of agriculture and ecological effects, the study found

(1) Despite the tremendous economic and human value of our agriculture production we have made very little progress in understanding how to measure pollution damage to agriculture yields. The study noted that "although air pollution problems have changed from local visible issues to that of an invisible plague, the means of identifying air pollution damage had not changed significantly over the past 5 decades."

(2) Even with our very minimal ability to measure chronic pollution damage to plant growth the study points out that there are still many cases where it is clear that injury occurs "at levels far below existing secondary standards." As just one example, exposure of alfalfa to SO_2 concentrations allowed by secondary standards can result in leaf injury ranging to nearly 20 percent. The researchers noted in conclusion that "the range of damages at various combinations of pollutants raises a serious question as to the adequacy of secondary standards."

(3) Both agricultural and ecological damage now extend far beyond the areas where polluting activities are concentrated, and many pollutants have significant global distribution.

(4) We have, in this country, no coherent system of monitoring general ecological effects of chronic pollution. For instance, despite world-wide recognition of the hazards of "acid rain" caused by chronic air pollution, the U.S. has "no

organized and systematic or consistent way to monitor the changes that occur in the chemistry of precipitation." This compares with a European system which has been continuously operated since 1947, and with a very extensive Swedish effort which has subjected about one-third of its total rainfall run-off to regular chemical analysis for more than ten years.

(5) Not only is our ecological research and monitoring in a primitive state, but we have not even taken any administrative steps to begin to remedy the situation. The responsibility for coordination and insurance of adequate ecological research and baseline data has not been accepted by, or assigned to, any Federal agency. Through a committee of the Council on Environmental Quality and the Federal Council on Science and Technology reviewed Federal ecological research in 1973 and found serious deficiencies, the recommendations for remedy have not been acted on.

In the case of climate, the study found

(1) We are becoming more aware that substantial climate change can be much more rapid than has sometimes been supposed. This, coupled with the recently observed sensitivity of world food supply to the weather in key producing areas, makes the assessment of man's role in perturbing climate an urgent need.

(2) Though the data gathering effort so far has been minimal, evidence already indicates that the pollutants of cities, and the changes of surface properties of the earth caused by man's activities, definitely affect climate in regions surrounding urban settlements.

(3) Because of the difficulty in distinguishing man-made change from natural cycles, we are unable to judge with current monitoring efforts the role of human activity in causing the current world-wide cooling trend.

(4) Considering the immense stakes involved in any gambles on inadvertent climate modification, full support by the U.S. of global monitoring and baseline measurement should be given high priority.

The CRS study clearly identified a number of research issues

(1) A key to many aspects of better understanding of chronic pollution effects will be better coordination and organization of Federal environmental research and development, and better coordination of the Federal program with State, local and regional efforts. The chronic effects are often diffuse, while serious, not necessarily dramatic. The study of low-level pollutants, then, requires more coordination and care than has been needed for acute levels of pollution.

(2) The amount of research in these areas ought to more nearly correspond to the potential costs of chronic pollution effects. These are only vaguely known, but appear to be on a scale which would indicate a much greater relative emphasis in the Federal health and environmental programs. Research ought to be addressed, in fact, to determining the true costs so that we could better judge how critical the problem is and how regulatory actions can be best balanced against economic and other societal values.

(3) New approaches to detecting and predicting health effects are urgently needed to manage intelligently chronic pollutants. Epidemiological and health survey studies may need to be expanded relative to traditional laboratory approaches.

(4) Ecological research, and especially well coordinated monitoring to establish baselines and trends of pollutants and ecological health, are very urgently needed. A first step will be to designate responsibility for development of a coordinated program using all the resources available in Federal, State and local environmental authorities, as well as in academic and other private institutions.

(5) Similar coordinated monitoring, and full participation in international, global efforts, is needed in climate research. The potential adverse effects of inadvertent climate modification are so great that a very large research effort is easily justified."

APPENDIX.—AN OUTLINE OF POSSIBLE LEGISLATION FOR THE REORGANIZATION OF ENVIRONMENTAL RESEARCH

The following outline indicates a possible form for legislation aimed at establishing a policy and organizational structure for federal environmental research. It is directed also at establishing a framework within which local, state and regional authorities can coordinate their efforts and draw on a variety of resources in addressing their local problems, and in which academic and other private institutions can operate independently but with sufficient sense of national goals and priorities to enable them to optimize the allocation of their own efforts. The proposal is given in a loose outline form, to emphasize that it is meant to promote discussion and suggestions of alternatives, and not at all to represent a fixed position. In addition to the outline points, it is intended that elements of H.R. 35, the Environmental Centers Bill, and H.R. 75, the Environmental Policy Institute Bill, might also be included.

The specifics of the legislation proposed are addressed to several key problems identified during several hearings before the Subcommittee on Environment and the Atmosphere in 1975:

1. There is no reliable mechanism for coordinating agency environmental research or even insuring communication among them.

2. There is no clear pattern of priorities, allocation of resources, or division of labor against which individual agency programs can be measured for effectiveness or consistency with national goals.

3. Regional, state and local environmental research and monitoring efforts are often wasted because non-standardized definitions of problems, methods, and results prevent blending these into a coherent whole.

4. Academic and private research institutions are handicapped in contributing to needed knowledge of environmental effects and control methodology because of the lack of identifiable long-range goals or problem definitions.

5. With the lack of clear responsibility for federal environmental research coordination and problem coverage, short-range research "emergencies" inevitably siphon off resources from important long-range concerns.

To meet these problems, proposed legislation could follow the attached outline.

Outline of Possible Environmental Research Reorganization Legislation

Section 1.—Establish as policy the need to:

a. maximize the benefits of national environmental research capabilities by establishing and up-dating well-defined goals and coordinating research efforts aimed at those goals.

b. involve local, state, and regional authorities, academic and private research institutions, and other groups in the goal and priority setting.

c. insure that environmental research proceeds at a pace sufficient to assess environmental consequences of technological, economic and social change, and to protect human health and ecological balance.

Section 2.—Establish in the Executive Office (probably in the Council on Environmental Quality or the Office of Science and Technology Policy, if created) a clear responsibility for coordination of environmental research and development activities. Duties of the responsible office would include:

a. providing staff assistance to the President in defining short and long-range problems meriting research and development effort.

b. performing a similar staff function in assessment of priorities among identified problems.

c. assisting the President in allocation of research resources and dividing tasks among federal agencies. This responsibility would include the definition of research programs to meet the needs of equitable standard setting, and the consideration of standard setting philosophy and methodology to meet the capabilities of contemporary research. It would also include convening of necessary inter-agency groupings to insure exchange of ideas and coordination of programs.

Section 3.—Provide a framework for maximizing the benefits and usefulness of environmental research in regional, state and local governmental authorities and in academic and other private research institutions. Authority would be required to:

a. insure the development and dissemination of standardized testing, monitoring and reporting technologies, and to facilitate exchange of research and observational results.

b. insure that regional, state and local innovations and problems are widely disseminated among environmental research organizations.

c. develop areas of consensus among regional, state and local authorities and non-governmental groups as to priorities among environmental research problems and desirable allocation of resources to them.

d. implement the requirements of paragraphs a), b), and c), by providing incentives for national and regional meetings, workshops, and training courses.

e. facilitate establishment of data systems of sufficient generality and standardization to permit expeditious accumulation of reliable baseline environmental data.

f. insure the wide-spread dissemination of the goals, priorities and plans of Section 1 to non-federal governmental authorities and private institutions to facilitate their own planning.

Section 4.—Establish a training and education plan for environmental specialists. This would be done by:

a. broadening the charter of land-grant universities to include responsibility and incentives for education of environmental professionals and technicians.

b. provide incentives for private research institutions to conduct training programs in the environmental sciences.

Section 5.—Establish a non-governmental advisory body for environmental research priorities. Responsibilities of this body would be:

a. to recommend and comment on the goals and priority-setting of Section 1.

b. to convene national and regional public hearings to develop and test consensus on the goals and priorities of Section 1.

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